Molten salt-loop development acceleration with distributed single-crystal harsh-environment optical fiber-sensors

Presented by: Michael Buric, NETL

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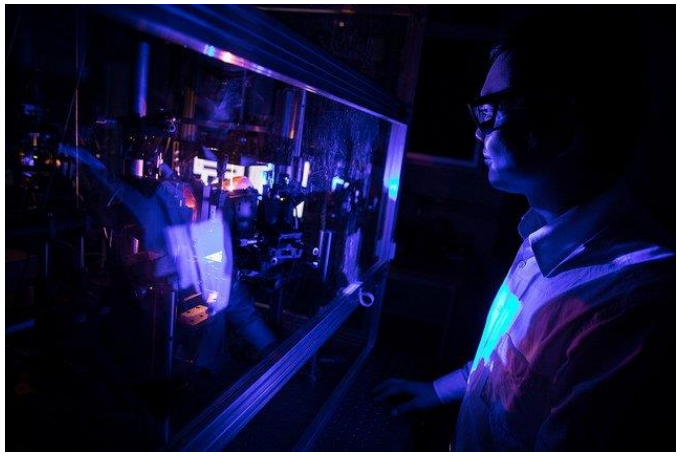
Crystal fiber distributed sensing

Project Objectives

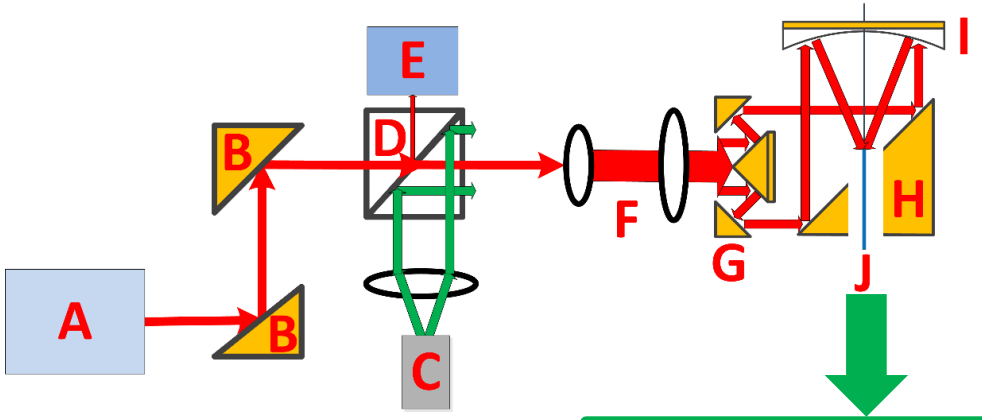
- Introducing fully-distributed sensing to Molten-Salt Reactors
- Growing new cladded single-crystal optical fibers for molten-salt environments
- Gathering thousands of data-points to map reactor coolant-path temperatures or other parameters
- Mapping in-core temperature distributions
- Next-gen sensing replaces single-point sensors like thermocouples
- Providing data to guide reactor design and improvement through thermal efficiency

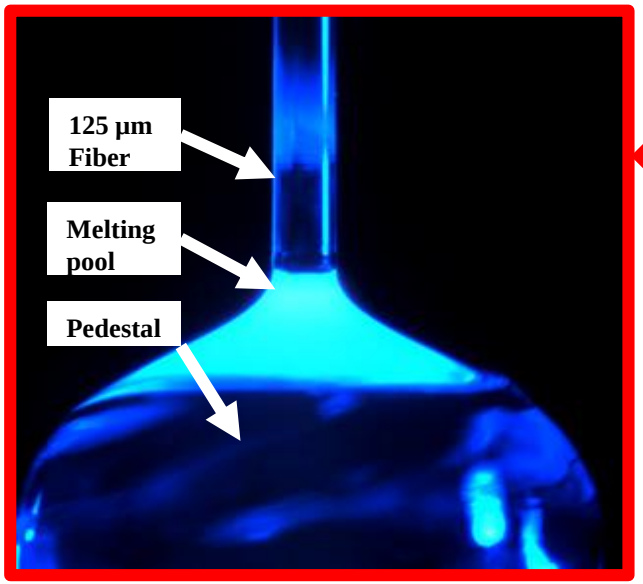


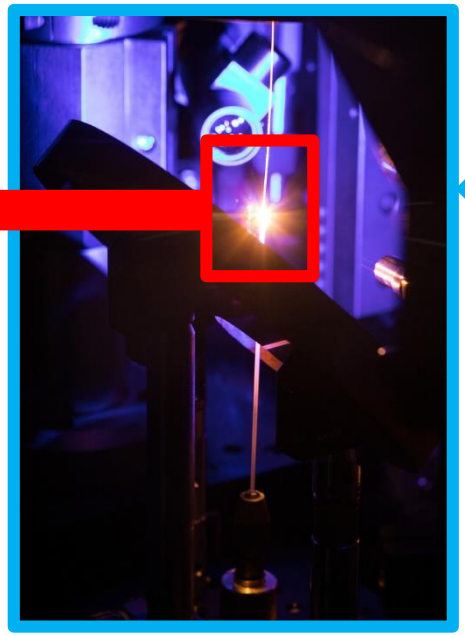
Crystal fiber distributed sensing - LHPG

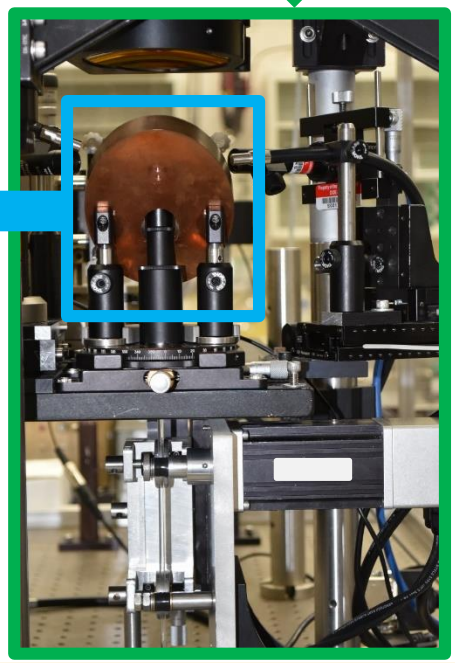
How LHPG works:

- **CO2 laser melts oxide feedstock**
- **Seed crystal lowered into melt**
- **Controlled motion of seed and feedstock upward**
- **Fiber is grown from the melt**









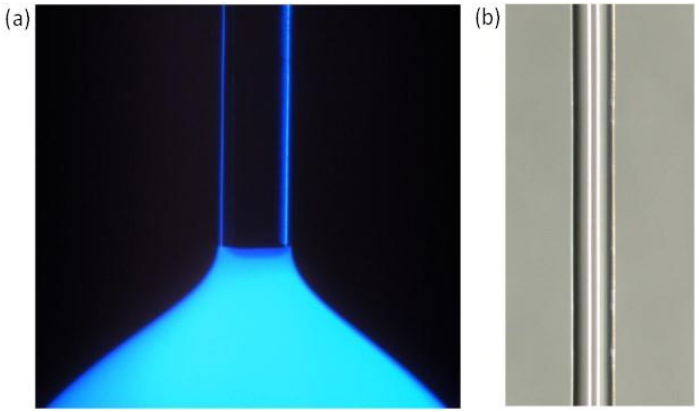
Crystal fiber distributed sensing

Team

- National Energy Technology Lab (fiber growth, sensor design, interrogator design)
  - Michael Buric (PI, fiber optics and systems)
  - Bo Liu (LHPG)
  - Subhabrata Bera (crystal cladding)
- Idaho National Lab (reactor expertise, system implementation and testing)
  - Pattrick Calderoni
    (in-pile instrumentation director, co-PI)
  - Joshua Daw (nuclear instrumentation)
  - Ruchi Gakkar (nuclear materials)
- MIT (material compatibility, efficacy simulations)
  - David Carpenter (Irradiation Engineering Director)
  - Koroush Shirvan (reactor design and simulation, co-PI)

Crystal fiber distributed sensing

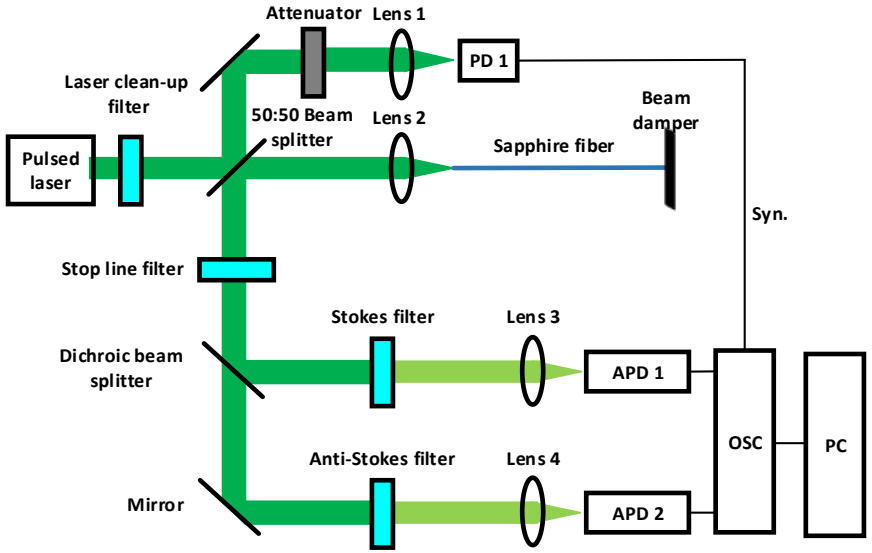
- First project quarter completed
- World's longest single-crystal fibers produced (~20m)
- Unique Distributed Raman interrogator for sapphire optical fiber completed
- 2nd LHPG system under construction
  - Only facility to operate 2 systems for feedstock and cladding growth
- Molten-salt test systems under construction
- Techno-economic parameter analysis under construction



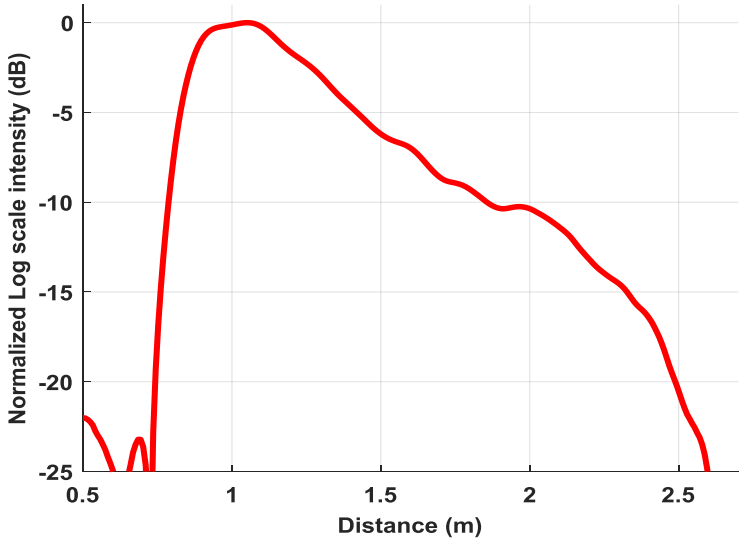
Crystal fiber distributed sensing

- Testing with Raman OTDR in salt baths, with gamma sources, and in the MIT Research Reactor
- Packaging preliminary work
- Longer-term operation

Raman OTDR, Liu et al Opt. Lett., 2016

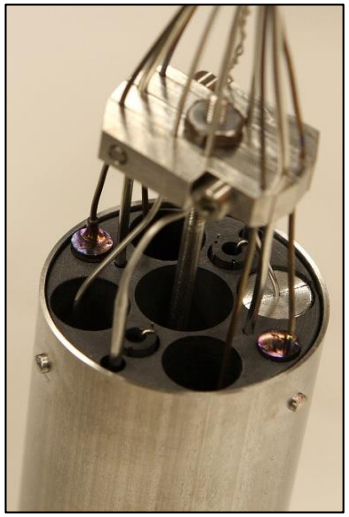


Sapphire fiber attenuation at 532nm, measured by a Raman OTDR system



Crystal fiber distributed sensing Technology-to-Market

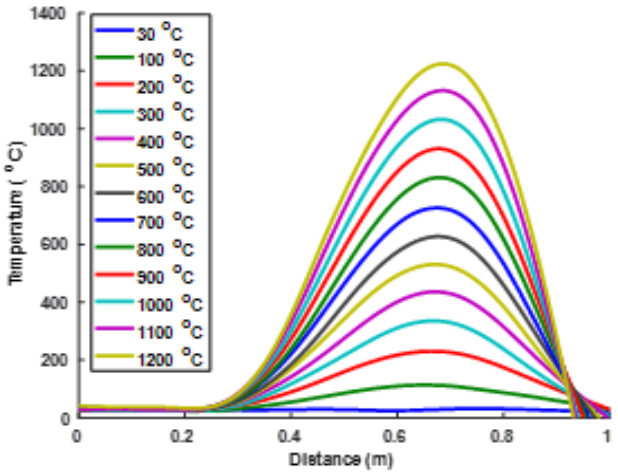
- Existing ROI on LHPG control algorithm, long-length fibers
- Ongoing T2M parameter study (MIT)
  - Which parameters (other than T) are most useful?
  - Which locations are highest value?
  - What efficiency gains can be made?
- Advisory interactions
  - Molten salt commercial developers poled
  - INL GAIN workshops
  - Pursue additional field testing for tech-transfer



Crystal fiber distributed sensing

Feedback

- After the first quarter – what can we learn?
- Insight on field-testing challenges
- Guidance on industry acceptance
  - Existing electricity producers resistant to new tech
  - Regulatory constraints on new tech
- Input on sensor-data value proposition
  - Operator Data “wish-list”
  - Designer primary challenges



Conclusions

- Distributed sensing is coming to numerous industries
- Optical fiber technology can extend into nuclear harsh-environments
- Interdisciplinary efforts needed for advanced sensors and controls
- Further collaboration between fossil/nuclear sectors needed
- Amazing new levels of visibility and automation are here!